NASA TECHNICAL TRANSLATION NASA TT F-11,463

NASA TT F-11,463

HORIZONS IN THE DEVELOPMENT OF AIRCRAFT AND CONCLUSIONS

S. I. Zonshayn

Translation of "Perspektivy Razvitiya Letatel'nykh
Apparatov i Zaklyucheniye"
In: Aerodinamika i Konstruktsiya Letatel'nykh Apparatov,
"Vysshaya Shkola" Press, Moscow, 1966, pp. 352-360

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 FEBRUARY 1968

7.3, the curve showing the increase in the weight of fighters each year), in bombers the passage through M = 1.0 was marked by a tendency toward a substantial decrease in weight.

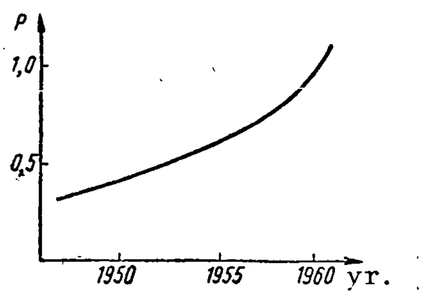

Figure 7.1. Yearly Increase in the Thrust-Weight Ratio.

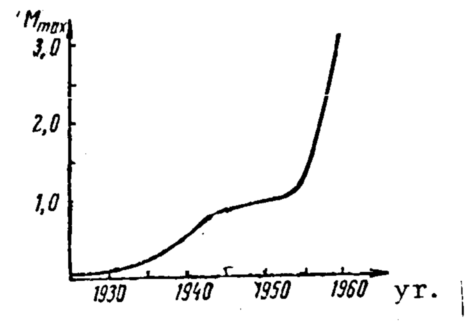

Figure 7.2. The Yearly Use of the Mach Number in Fighters.

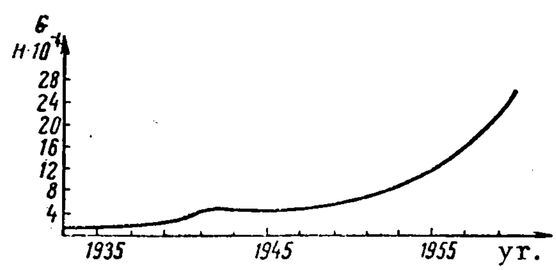

Figure 7.3. Curve of Change in Weight of Fighters with Time.

The drop of the curve in Figure 7.4 after 1955 is explained by the fact that the weight for subsonic bombers is more than double that of supersonic bombers.

This is explained by the fact that although the increase in the thrust-weight ratio in fighters was aided by the substantially faster rate of increase of thrust in the engines than the increase of weight, less suitable conditions were /354 found in bombers: for them an increase in the thrust-weight ratio could be achieved only through a decrease in weight inasmuch as increase in engine thrust was disproportionate to the increase in the weight of the aircraft.

A tendency has been noted in decreasing the weight of fighters as well. However, the development of older types, represented by the statistical graphs in Figure 7.3, is impossible. Progress demands the creation of a new class of light, high-speed fighters with a weight one half or one quarter that of the so-called all-weather fighters.

Beyond Mach numbers of the of 3.0, the use of piloted fighters and bombers merges with that of pilotless aircraft, basically air-to-air, surface-to-air and surface-to-surface missiles.

From 1945 to 1955, the takeoff and landing of high-speed aircraft demanded airfields which were sizable in both dimensions and cost which, along with the economic factor -- expense -- lead to a decrease in the mobility of the Air Force and sharply restricted its capability of working in conjunction with ground troops. Therefore research began on plans and designs for aircraft which might

CHAPTER VII

HORIZONS IN THE DEVELOPMENT OF AIRCRAFT AND CONCLUSIONS

ABSTRACT. The development of aircraft is seen to be a function of the development of engines and other components, particularly engines. In the future, piloted aircraft will be developed on the same bases as in the past, but with increased demands as to speed, range, etc. The effects of these demands are analyzed.

Throughout this course we have come to see that the development of aircraft is a function of the development of engines and the multiform complex of equipment, including electrical and radial apparatuses. /352

The tie is especially close between the construction of aircraft and that of engines, on whose characteristics depend the flight capabilities of the engine-aircraft system.

Those demands in the development of aircraft resulting from the needs of the national economy and defense of the country also obviously determine the development of propulsion units and equipment.

The constantly increasing rates of development of science, technology and production capabilities as a whole offer aviation broad horizons.

The basic trends determining the development of aircraft in the past -- the struggle for increased speed, altitude and flight range -- remain the guide book to the future as well. However, recently new demands have arisen, especially in terms of the range of speeds, which have determined the birth and development of new branches of aviation.

The opinions that the basic types of aircraft in the past -- piloted aircraft -- have outlived their time and should make way for pilotless aircraft are baseless. All types of aircraft, both piloted and pilotless, independent of the type of engine and design, are capable of development and have horizons for their development. However, there is no doubt that individual classes of aircraft, depending on and resulting from the capabilities of their engines, will achieve various uses.

As we have seen earlier, the chief parameter determining an aircraft's flight properties, depending on the data for the engine, is the thrust-weight ratio $\overline{P}$.

Figure 7.1 shows the change in the values of this parameter by years. /353
Whereas at the very beginning of the development of jet aircraft $\overline{P} = 0.2$, now it exceeds 1.0 and is capable of future increase. Along with the increase in the values of this parameter, the maximum velocity of military aircraft has increased. The curves in Figures 7.1 and 7.2 show that the passage through the value $\overline{P} = 0.5$ has permitted reaching the speed of sound, $C\overline{P} > 1.0$ not only permitted supersonic flight possible, but fighter speeds greater than twice that of sound, and permitted the rise of aircraft with a large thrust-weight ratio.

High-speed bombers including heavy bombers (such as the B-58 Hustler) have not lagged far behind fighters in terms of speed. However, although in fighters the thrust-weight ratio increased as the craft's flight weight increased (Figure possess sharply decreased takeoff and landing distances. In addition to the classical aircraft, helicopter and rocket, every possible combination of these basic types of aircraft was developed and new structural shapes in aircraft appeared, right up to wingless aircraft.

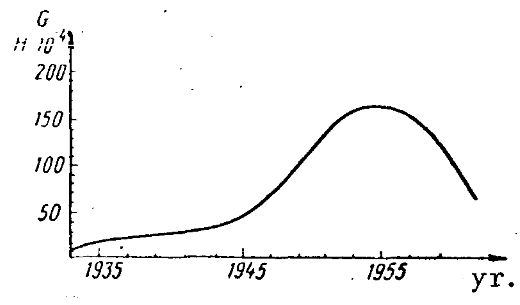

Figure 7.4. Change in the Yearly Weight of Heavy Bombers.

The limits in the development of each type of aircraft were intimately related to the capabilities of the engines, whose properties, as has already been noted, are the dominant factor in determining the capabilities of the aircraft.

A characteristic index for engines, on whose size depends the range of effective use of the various types of propulsion units, is the coefficient of weight effectiveness w -- the relationship between the sum of the engine weight and the fuel required for flight of a set duration to the product of the free thrust value for the flight time

$$w = \frac{G_e + G_T}{P_f t_r}. \qquad (7.1)$$

Free thrust is the amount of engine thrust per decrease in thrust required to propell the engine itself and the fuel. /355

The lower the value of this ratio, the more suitable the engine will be for given flight conditions.

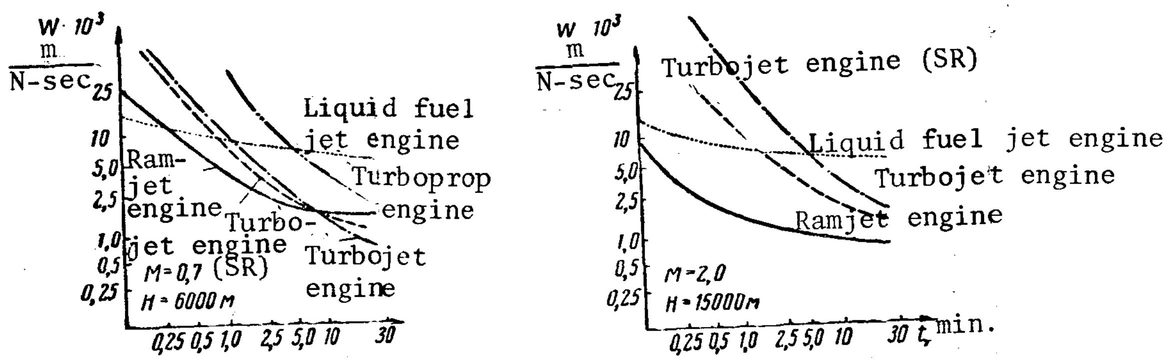

Figure 7.5. Curve W = f(t)

Figure 7.5 gives the curve for the changes in w according to t for various engines during flight at height H = 6000 m with M = 0.7 and for H = 15,000 m with M = 2.0.

From the graphs it can be seen that even in subsonic flight, a rocket engine is competitive with any other for short-duration flight. It exceeds all engines when flying "on gas" for 15 seconds and is surpassed by the turbojet engine only for durations exceeding one minute. In the supersonic range with M = 2.0, the best engine of all is the ramjet. As far as the liquid-fuel engine is concerned, while falling behind the ramjet engine in all ranges, it has an advantage over the turbojet in flights under two minutes.

The advantages of the ramjet are quite appreciable when flying a good distance at supersonic velocities.

The optimum use of the turbojet in modern flight is the Mach number M = 2.5. However, above this Mach number the range continuous to increase although for M > 2.3 ramjet-powered aircraft are most suitable in terms of range. This can be seen from Figure 7.6, in which the curves for the range factor (k_L = L/const) are given in terms of M. From the graph it is clear that in flights through dense air, aircraft with liquid-fuel engines lag behind air-breathing jet engines /356 even for Mach numbers exceeding six and that when M > 2.3, aircraft with ramjet engines are more suitable than those with turbojets.

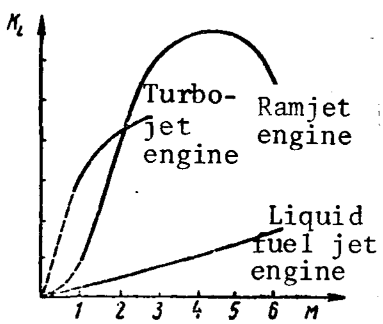

Figure 7.6. Values of Range Coeffients.

Let us recall once more that fitting an aircraft only with a ramjet does not give it takeoff independence. Therefore, when a ramjet is installed, it is combined with other types of engines: either a liquid-fuel engine (or solid-fuel rocket engines) or with a turbojet engine. Because of the large specific consumptions of fuel characteristic of rocket engines, combinations of ramjet and rocket engines do not yield very extended flight. The combination of the ramjet and the turbojet is more suitable and permits long-range supersonic flight. Such a combined engine is more suitable than the turbojet with afterburner inasmuch as the afterburner has substantially lower efficiency for M > 2.0. The efficiency of a combined engine continues to increase for higher Mach numbers if we bear in mind that the midsection of a combined ramjet + turbojet is smaller than that of a turbojet with afterburner (for the same ultimate conditions in terms of the amount of required thrust), the future of aircraft and other flight craft with similar combined engines becomes clear. Figure 7.7 shows an aircraft (the Griffon) with a combined engine. Figure 7.8, which shows the Bomarc missile, gives an idea of an aircraft with ramjet engines in combination with jets. The value of the ramjet and turbojet combination makes the Coleoptera, in which it will be remembered that the diffuser of the ramjet engine can annular wing, highly challenging.

The introduction of atomic engines into use has offered a substantial increase in the flight capabilities of aircraft, especially in terms of range. Without going into the details of such possible designs, let us note that atomic engines which transmit their energy to either a propeller or as jet power are both possible. Atomic jet engines will obviously find application in high- /357 speed aircraft. Figure 7.9 shows a plan for a transport aircraft with an atomic engine. Plans for jet aircraft show that externally they would differ little from normal aircraft; their only distinguishing feature would be the increased length of the fuselage and the tendency to locate the reactor as far from the cabin and men as possible. The use of atomic energy represents a breakthrough in the creation of ion, photon and similar engines which will achieve long-range space flight.

Only the rocket engine from among all /358 existing engines offers flight in the highly rarified air at altitudes exceeding 30 to 40 km and beyond the limits of the atmosphere.

Tests in launching artificial earth satellites and spacecraft allows us to make some judgements on the trends in the development of aircraft which will put man into outer space and open the way for flights to other planets.

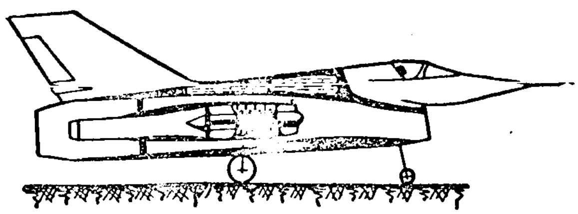

Figure 7.7. Diagram of an Aircraft with Combined Engines.

Such are the more-or-less long-range challenges in the development of aircraft, but there are also the short-range challenges relating to the field of flight at low altitudes within the atmosphere.

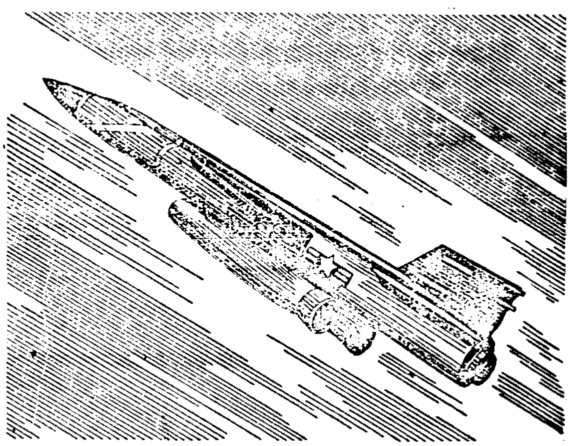

Figure 7.8. The Bomarc Missile with a Ramjet Engine in Combination with a Rocket Engine.

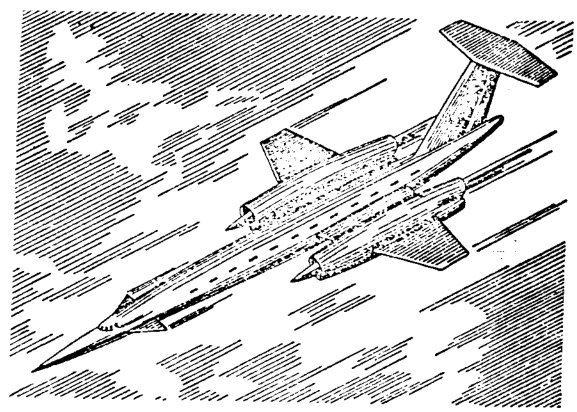

Figure 7.9. Proposed Type of Long-Range Aircraft with Atomic Engines.

The trends in the use of rotors (propellers) in cowlings as well as the branch dealing with wingless aircraft are quite promising. The possible development of the first type of aircraft with broad ranges of flight velocities may be judged from the Breguet Company's planned aircraft shown in Figure 7.10.

The second trend is illustrated by the photograph of a model (Figure 7.11) which was successfully used to study the principle of wingless flight.

High-speed aircraft -- both winged and wingless -- will appear which will /359
perform vertical takeoff and landing (VTOL) as well as fantastic supersonic velocities flying at altitudes where intolerable heating can be avoided.

An example of such a passenger aircraft with a Mach number M = 7.0, being planned by the Lochheed Company, is shown in Figure 7.12.

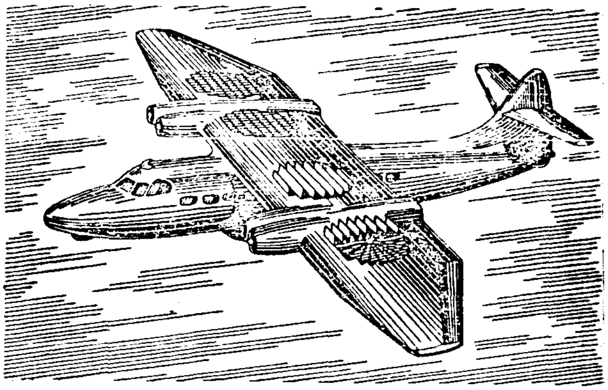

Figure 7.10. Projected VTOL Aircraft using Fan-Type "Motion Generators" (Breguet).

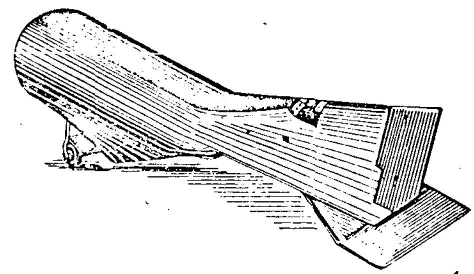

Figure 7.11. Model of Wingless Aircraft with Internal Continuous Channel Flow.

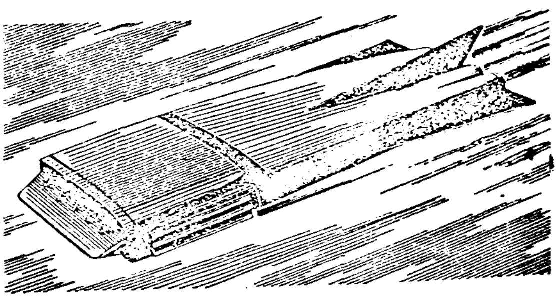

Figure 7.12. Passenger Aircraft with M = 7.0 planned by the Lochheed Company.

It must be noted that along with the development of aviation, both the amount of equipment installed in aircraft and the complexity of this equipment have equally grown. This is especially true with respect to pilotless aircraft.

The switch toward large transonic (sub-space and supersonic) velocities has entailed many specialized problem such as, for example, the struggle against the high temperatures on the surface of the aircraft.

The growth of jet aviation constantly sets up newer and newer problems in terms of aerodynamics, strength of materials, aircraft materials, engine construction, mechanics and other branches of aviation technology.

The central problems in the development of aircraft construction have remained the struggle for flight safety and the overall increase in economy. However, the solution to these problems under the new flight conditions at high speeds, particularly supersonic speeds, in turn demands new approaches. For example, whereas the increase in cruising speeds for transport aircraft decrease economy as they approach the transonic zone, in the supersonic regions, as the respective investigations have shown, as the flight Mach number increases up to values of M = 2.5 - 3.0, economy improves.

The increase in aircraft flight velocities above M = 3.0 in the dense layers of the atmosphere is substantially hindered due to kinetic heating. This fact can contribute substantially to clarifying the demarcation in the zones for aircraft and rockets, which today is still complicated. In doing so, however, we cannot ignore those boundaries determined by the lifting capacity and demands for strength.

In Figure 7.13, curve 1 characterizes the limit of the region in which the aerodynamic lifting capacity is insufficient to permit horizontal flight; curve 2 represents that region in which kinetic heating causes the surface temperature on aircraft to exceed 1200°C; curve 3 is the limit of strength characterizing the region where the velocity head exceeds 15,000 n/m^2. Only the small area of the graph corresponds to the abilities of aircraft to fully use their engines. This is region A. Region B, lying within the zone between the first and second space velocities, represents the capabilities of artificial earth satellites and space rockets. Region C encompasses the relatively narrow corridor in which equilibrium flight is possible with the use of all the means of achieving lift. This is the region in which spacecraft, rocket aircraft and similar aircraft can land. /360

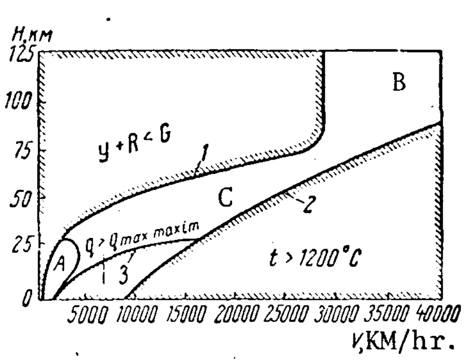

Figure 7.13. The Limits of Regions in which Established Flight without Limitation is Possible.

A certain broadening of region A is feasible through the perfection of air-breathing rockets and their combinations with liquid-fuel rockets.

The historic flights of our cosmonauts laid the beginning of conquering region B and yielded data for evaluating flight conditions in region C.

The perfection of materials and the designs of shells, systematic work in increasing the effectiveness of chemical propellent, the creation of rocket engines using atomic energy and electrical jet engines have been the bases for furthering the development of spacecraft.

We are close to achieving Tsiolkovskiy's idea of creating artificial satellites -- interplanetary stations which will be the basis for outfitting gigantic spacecraft.

Automatic scouts such as the Mars-1 and Zond-3 studying outer space help us accumulate the necessary data for flights to both the near and far planets.

Both overall problems and the multitudinous special problems arising in the creation of highly challenging aircraft are being solved on a broad front. This constitutes our guarantee of the success of future achievements in all aspects of aviation technology.

REFERENCES

1. Fabrikant, N.Ya.: Aerodinamika [Aerodynamics], Nauka Press, 1964. /361
2. Martynov, A.K.: Eksperimental'naya Aerodinamika [Experimental Aerodynamics], Oborongiz Press, 1958.
3. Levinson, Ya.I.: Aerodinamika Bol'shikh Skorostey [High-Speed Aerodynamics], Oborongiz Press, 1948.
4. Goshek, I.: Aerodinamika Bol'shikh Skorostey [High-Speed Aerodynamics], Foreign Literature Press, 1954.
5. Hilton, W.F.: High-Speed Aerodynamics, Foreign Literature Press, 1955.
6. Ostoslavskiy, I.V.: Aerodinamika Smaoleta [Aircraft Aerodynamics], Oborongiz Press, 1957.
7. Lebedev, A.A. and L.S. Chernobrovkin: Dinamika Poleta [Dynamics of Flight], Oborongiz Press, 1962.
8. Bel'skiy, V.L. and I.P. Vlasov (et al) S.N. Kan - editor, Konstruksiya Letatel'nykh Apparatov [Design of Aircraft], Oborongiz Press, 1962.
9. Glagolev, A.N., Zhulev, V.I. and E.M. Sobolev: Konstruktsiya i Boyevaya Effektivnost' Letatel'nykh Apparatov [The Design and Combat Effectiveness of Aircraft], VVIA Press, 1963.
10. Fomin, N.A.: Proyektirovaniye Samoleta [The Design of Aircraft], Oborongiz Press, 1963.
11. Feodos'yev, V.I. and G.B. Sinyarev: Vvedeniye v Raketnuyu Tekhniku [Introduction to Rocket Technology], Oborongiz Press, 1960.
12. Besserer, K.U.: Praktika konstruirovaniya i rascheta upravlayemykh snaryadov [The Planning and Design of Guided Missiles], Fizmatizdat Press, 1960.
13. Lokk, A.S.: Upravleniye Snaryadami [Missile Guidance], Fizmatizdat Press, 1958.
14. Merill, G.: Issledovaniye Operatsiy [The Study of Operations], Fizmatizdat Press, 1959.
15. Burgess: [Guided Missiles], Foreign Literature Press, 1958.
16. Marisov and Kucherov: Upravlyayemyye Sharyady [Guided Missiles], Voyenizdat Press, 1959.

Translated for the National Aeronautics and Space Administration under contract No. NASw-1695 by Techtran Corporation, P.O. Box 729, Glen Burnie, Maryland 21061